Upper Extremity Robot Therapy for Individuals with Spinal Cord Injury

Bui KT, Sprigle S, Backus D

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Background : Spinal Cord Injury (SCI)

- SCI annual incidence in the U.S.
  - 11,000 new cases per year
- SCI prevalence in the U.S. 2006
  - 253,000 people
- Statistics
  - Average age at injury: 28 yrs
  - Gender: 77.8% males
  - Etiology: 46.9% from motor vehicle accident
- Impairment or loss of motor/sensory function
  - Tetraplegia – impaired function of arms, trunk, legs, pelvic organs
  - Paraplegia – impaired function of trunk, legs, pelvic organs

http://www.fscip.org/facts.htm

Background: Recovery After SCI

- Functional recovery of some muscles can occur for several years after incomplete SCI
  - Recovery depends on the reorganization of preserved nerve connections and formation of new connections [Beekhuizen 2005]

- Cortical reorganization
  - Reorganization is associated with activity [Beekhuizen 2005, Fasioli 2003, Raintenteau 2001]
  - Cortical reorganization occurs after SCI as it does after stroke [Beekhuizen 2005]

- SCI recovery mechanism is similar to that in stroke subjects
  - Interventions used after stroke have demonstrated potential to improve strength after SCI [Beekhuizen 2005]

Background: Robotic therapy

- Current use: rehabilitation for motor impairment and limb weakness after stroke [Fasioli 2003]
- Therapy modes: passive & active-assisted, active-resisted [Stein 2004]
- Results
  - improved motor coordination and strength in early stroke subjects
  - reduced motor impairment in moderate to chronic stroke subjects [Fasioli 2003]
- Advantages: precise repetitive movements, quantitative performance monitoring, staffing/budget, compliments conventional therapy [Dikers 1991, Colombo 2005, Reinkensmeyer 2000]
- Disadvantages: generic treatment protocols, unable to identify specific benefits of each therapy modality [Stein 2004]

Robotic Device: Muscle Tech

- Background
  - Designed by Muscle Tech company in Israel
- Functions
  - Elbow flexion/extension
  - Forearm pronation/supination
- Setup
  - Device stands independently to side of wheelchair
  - Controlled through computer program

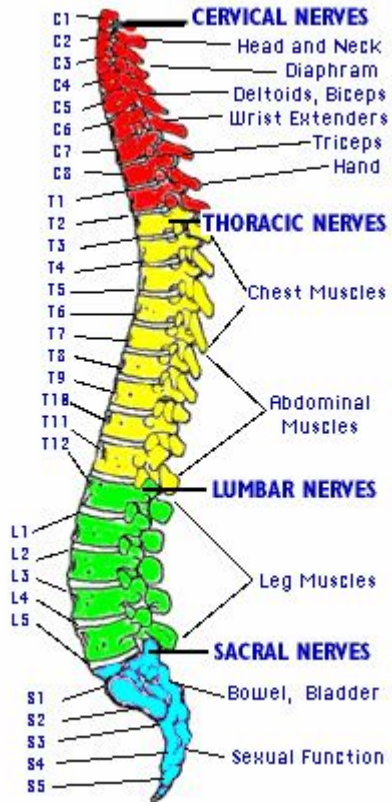
Objectives

- **Phase 1**
  - **Assess usability**: safety, comfort, ease of use, fit and exercise protocol in order to optimize the device
- **Phase 2**
  - Investigate effectiveness of robotic exercises for **strengthening** after SCI

Inclusion Criteria

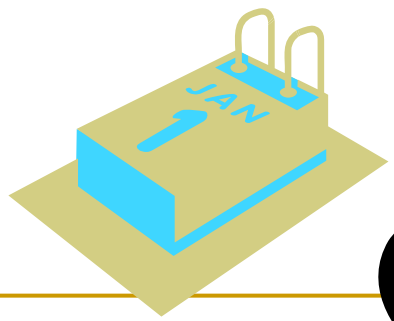
Phase 1

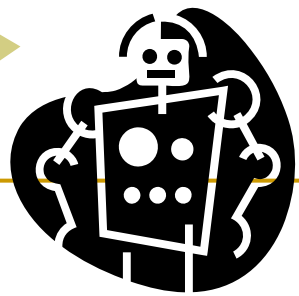
- SCI level C5, C6, or C7
- ASIA impairment B, C, or D
- Male or female
- 18 - 59 years old
- Tolerate sitting upright at 90 degrees for at least one hour
- Demonstrate at least 50% of normal range of motion (ROM) for each joint involved in this therapy
- Palpable contraction (grade 1-3) in the biceps and triceps
- Chronic impairment



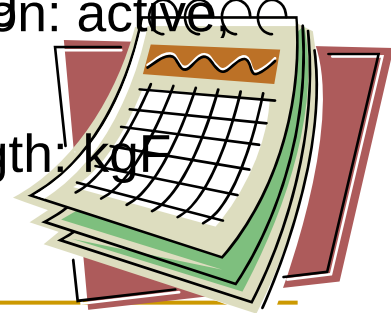
Study Protocol

- Phase 1: 3 hr session
  - Pre-treatment
    - Clinical Assessment
    - Robotic Evaluation
  - Treatment
    - 1 hr robot exercises
  - Post-study Questionnaire
    - Subjects





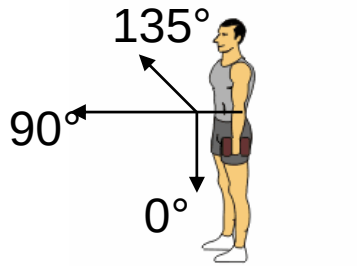
- Pre-treatment
- Robotic Exercises
- Post-study Questionnaire
- Design optimization
- Modalities
- Passive assisted movement
- Comfortable resistance, muscle stretching
- Treatment
- Isometric contraction
- Therapeutic usefulness
- 1 hr robot exercises
- Strengthening
- 3 days/wk, 4 wks
- Active resisted movement
- Robotic Evaluation
- Post-study Questionnaire
- Strengthening
- range of motion: active, passive
- Subjects
- Clinicians
- muscle strength: kgF



Results – Phase 1: Pre-treatment

- Subjects
  - 3 males, 2 females
  - Ages: 19 – 46 yrs
  - Injury year: 1980-2006

- IRB approval
  - Georgia Institute of Technology
  - Shepherd Center
  - Emory University



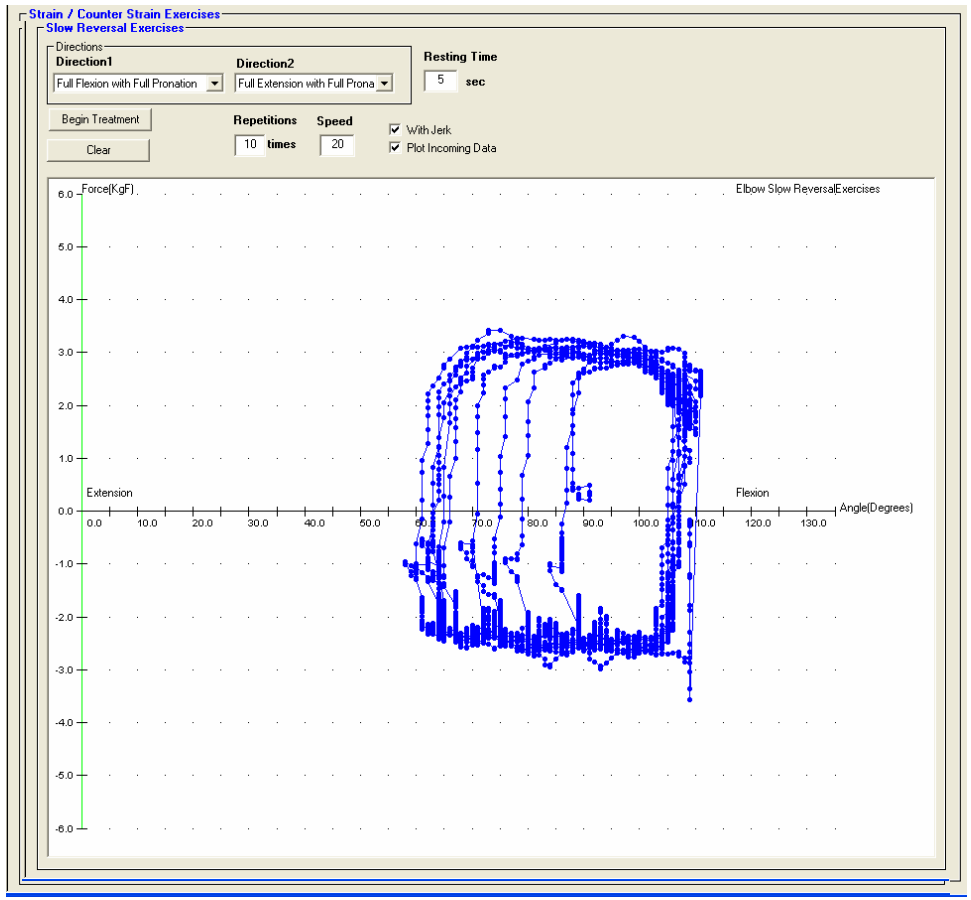
- PROM average

Treatment Arm	Clinical	Robot
Elbow Flexion	135°	110°
Elbow Extension	4°	27°

- Device limitations
  - Flexion limit: 110 degrees
  - Extension: subject selected end point

Results – Phase 1: Treatment

- Subject #3
  - Passive-assisted
  - Isometric contraction
  - Active-resisted



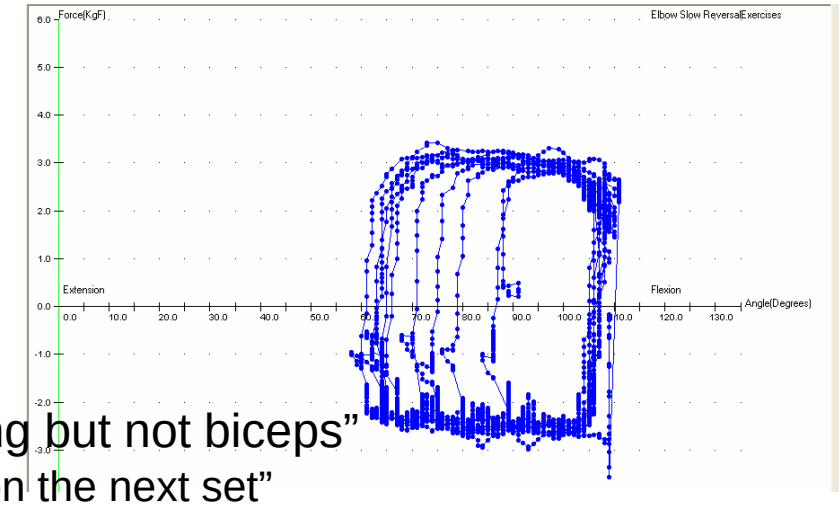
Results – Phase 1: Questionnaire

- Safety (9/10)
  - “felt safe with padding and splint”
  - “didn’t feel it squeeze”
  - “ROM limits were good”
- Comfort (8.6/10)
  - “snug fit”
  - “exercising is uncomfortable, not the machine b/c is was padded well”
  - “arm cuff not wide enough for larger arm”
  - “pressure at wrist but with breaks between exercises it was not an issue”
- Design ideas
  - Flexible plastic arm section to expand and conform
  - Modify splint to redistribute pressure at wrist

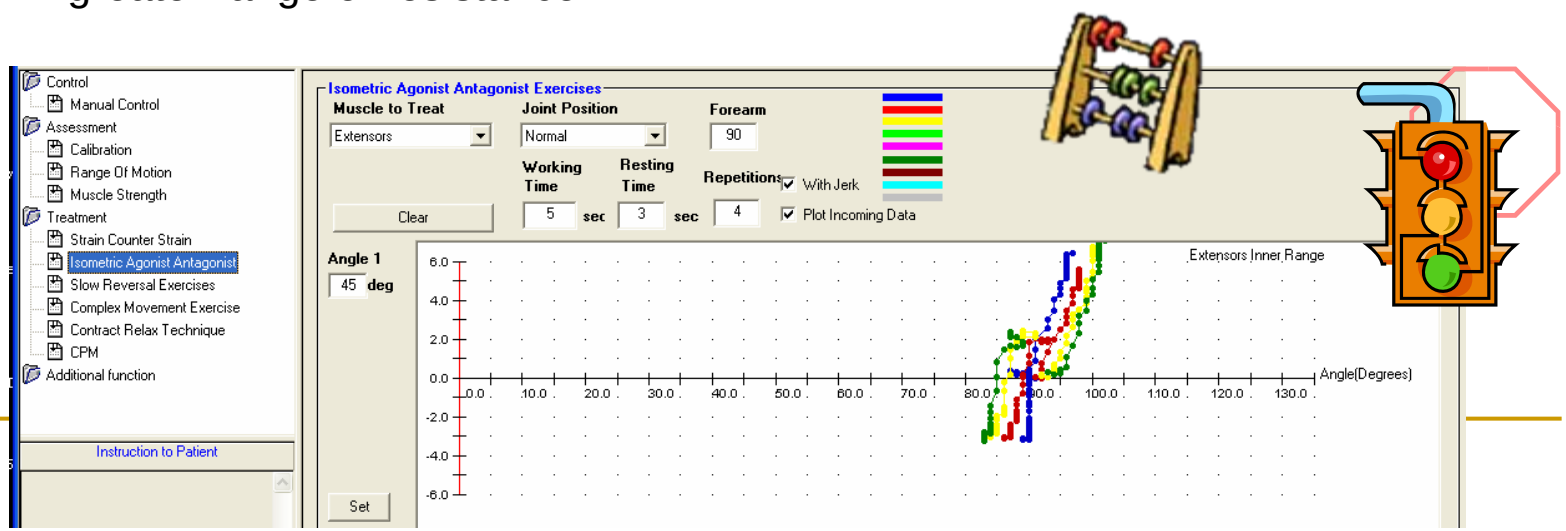
Results – Phase 1: Questionnaire

- Ease of Use
  - Don (4.2/10)
    - “tetraplegics need assistance or initial set up”
    - “rings on velcro straps”
  - Use (7.6/10)
    - “need instructions for exercises”
  - Doff (6.4/10)
    - “rings on velcro straps”
    - “no buttons”
- Fit
  - Of arm in device (8.4/10)
    - “straps and pads helped the fit”
    - “one-size arm section was tight on larger arm”
  - Security during exercise (9.2/10)
- Design ideas
  - Rings on velcro straps

Results – Phase 1: Questionnaire

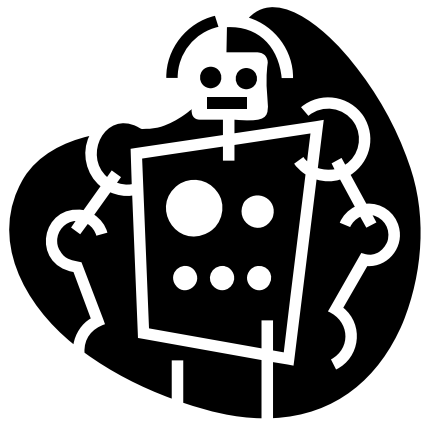


- Therapy
  - Challenging (8.4/10)
  - Motivating (7.4/10)
    - "Triceps exercises were challenging but not biceps"
    - "colored graphs made me try harder on the next set"
    - "how many more repetitions?"
    - "signals for stop/go not always clear"
  - Strengthening (7.6/10)
    - "enough exercise but not exhausting"
    - "may be good for recently injured person"
    - "maintaining strength is more important than building up"
  - Design Ideas:
    - color code all graphs, repetition counter, stop/go signal on computer screen
    - "don't know how much I can build up the muscles I still use"
    - greater range of resistance



Discussion

- Future Design Considerations
  - Robot exercises vs. hand weights
    - Safety – risk of stretching muscle
    - Independence
    - Measures of improvement
    - Interest in technology
  - Home device vs. therapist tool
    - Level of assistance to set-up and operate
    - Portable or permanently fixed



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